

## Claims

- 5003  
1. A system for acquiring seismic data, comprising:  
one or more sensor modules adapted to sense seismic data; and  
one or more seismic recorders adapted to record seismic data and  
coupled to the sensor module;  
wherein the sensor module comprises one or more accelerometers, and  
wherein the accelerometers have one or more axes of sensitivity.
2. An apparatus for sensing seismic energy, comprising:  
a sensor adapted to sense seismic energy;  
wherein the sensor comprises one or more accelerometers, and  
wherein the accelerometers include one or more axes of sensitivity.
3. An apparatus for sensing seismic energy, comprising:  
a sensor adapted to sense seismic energy;  
wherein the sensor comprises one or more micro-machined sensor  
elements.
4. An apparatus for synchronizing the operation of a sensor to a common  
time base, comprising:  
a sensor module adapted to sense seismic energy;  
wherein the sensor module comprises one or more sensors, and  
wherein the sensor module further comprises a global positioning  
system receiver adapted to synchronize the operation of the sensors.
5. An apparatus for synchronizing the operation of a sensor to a common  
time base, comprising:  
one or more accelerometers adapted to sense seismic energy; and  
a seismic recorder coupled to the accelerometers;  
wherein the seismic recorder comprises a global positioning system  
receiver adapted to synchronize the sensor.
6. An apparatus for determining the position of a sensor, comprising:  
a sensor module adapted to sense seismic energy;  
wherein the sensor module comprises a global positioning system  
receiver adapted to determine the location of the sensor module.

- 1 7. An apparatus with insensitivity to tilt for sensing seismic energy,  
2 comprising:  
3 a sensor adapted to sense seismic energy;  
4 a feedback control circuit adapted to provide force balanced feedback  
5 coupled to the sensor; and  
6 a controller adapted to monitor the operation of the apparatus coupled  
7 to the sensor.
- 1 8. An apparatus for determining the orientation of a sensor, comprising:  
2 a sensor module adapted to sense seismic energy; and  
3 a controller adapted to control the operation of the apparatus coupled to  
4 the sensor module;  
5 wherein the sensor module comprises a 3-axis magnetometer adapted to  
6 determine the orientation of the sensor module.
- 1 9. An apparatus for determining the coupling between a sensor and the  
2 ground, comprising:  
3 a sensor adapted to sense seismic energy;  
4 a crystal assembly adapted to provide a force in order to measure the  
5 ground coupling of the sensor coupled to the sensor; and  
6 a controller adapted to control the operation of the apparatus coupled to  
7 the sensor.
- 1 10. An apparatus for measuring the vector fidelity of a sensor, comprising:  
2 a sensor adapted to sense seismic energy;  
3 a crystal assembly adapted to provide a force in order to measure the  
4 vector fidelity of the sensor coupled to the sensor; and  
5 a controller adapted to control the operation of the apparatus coupled to  
6 the sensor.
- 1 11. A method of seismic sensing, comprising;  
2 monitoring acceleration in a plurality of directions.
- 1 12. A method of seismic sensing, comprising;  
2 monitoring acceleration in a plurality of directions; and  
3 monitoring pressure variations.

- 1 13. A method of operating a sensor adapted to sense seismic energy with  
2 insensitivity to tilt, comprising:  
3 providing a forced feedback compensation to the sensor.
- 1 14. A method of determining the tilt angle of a sensor module adapted to  
2 sense seismic energy, comprising:  
3 providing a forced feedback compensation to the sensor; and  
4 measuring the steady-state gravity field over a predetermined time  
5 period.
- 1 15. A method of determining the tilt angle of a sensor module, comprising:  
2 calibrating the sensor module to determine tilt information;  
3 storing the tilt information within the sensor module; and  
4 measuring an effect of gravity on the sensor module.
- 1 16. A method of manufacturing a sensor assembly having a plurality of axes of  
2 sensitivity, comprising:  
3 minimizing cross-axis sensitivity;  
4 minimizing the tolerance of the sensitivity; and  
5 providing axes of sensitivity that are approximately orthogonal;  
6 wherein the sensor assembly operates with a vector fidelity uncertainty  
7 less than about 1%.
- 1 17. A method for acquiring seismic data, comprising:  
2 coupling a seismic recorder to a sensor module including a  
3 plurality of accelerometers.
- 1 18. A method of determining the orientation of a 3-axis sensor, comprising;  
2 performing a 3-dimensional measurement of a gravity field;  
3 determining a gravity vector;  
4 performing a 3-dimensional measurement of a magnetic field;  
5 determining a magnetic vector; and  
6 determining the direction of magnetic north and gravity down.
- 1 19. A method of sensing seismic energy, comprising:  
2 synchronizing the operation of a seismic sensor module;  
3 wherein synchronizing the operation of a seismic sensor module

- 4 comprises using a global positioning system signal from a global  
5 positioning system receiver within the sensor module.
- 1 20. A method of sensing seismic energy, comprising:  
2 determining the position of the seismic sensor;  
3 wherein determining the position of the seismic sensor comprises using  
4 a global positioning system signal from a global positioning system  
5 receiver within the sensor module.
- 1 21. A method of synchronizing the acquisition of seismic data, comprising:  
2 receiving a signal containing time information; and  
3 controlling the operation of one or more accelerometers adapted to  
4 sense seismic energy and one or more seismic recorders using the  
5 signal.
- 1 22. A method of determining the location of the acquisition of seismic data,  
2 comprising:  
3 receiving a signal containing position information; and  
4 determining the position of one or more seismic sensors using the  
5 signal.
- 1 23. A method of determining the degree of coupling between a sensor  
2 assembly and the ground, comprising:  
3 generating a force;  
4 recording a response of the sensor assembly to the force; and  
5 analyzing the response.
- 1 24. A method of determining the vector fidelity of a sensor assembly,  
2 comprising:  
3 generating a force;  
4 recording a response of the sensor assembly to the force; and  
5 analyzing the response.
- 1 25. A method of determining the orientation of a sensor module, including one  
2 or more accelerometers, without direct measurement, comprising:  
3 generating a force at a plurality of source points;  
4 recording a response of the sensor module to the force; and  
5 analyzing the response.

- 1 26. A method of determining the state-of-health for a sensor module,  
2 including a plurality of accelerometers and a seismic recorder, comprising:  
3 sending a bitstream to the sensor module;  
4 decoding, capturing, and looping-back the bitstream to the seismic  
5 recorder; and  
6 capturing and analyzing the bitstream by the seismic recorder,  
7 wherein analyzing the bitstream comprises determining a malfunction  
8 of the sensor module.
- 9 27. A method of determining the state-of-health for a sensor assembly,  
10 including an ASIC coupled to a seismic recorder, comprising:  
11 sending a bitstream to the ASIC;  
12 decoding, capturing, and looping-back the bitstream to the seismic  
13 recorder; and  
14 capturing and analyzing the bitstream by the seismic recorder;  
15 wherein analyzing the bitstream comprises determining a malfunction  
16 of the sensor assembly.
- 1 28. A method of determining the state-of-health for a sensor assembly adapted  
2 to sense seismic energy, including an ASIC, comprising:  
3 reading contents of the ASIC; and  
4 validating the contents of the ASIC.
- 1 29. A method of determining the state-of-health for a sensor assembly adapted  
2 to sense seismic energy, including an accelerometer, comprising:  
3 operating the accelerometer; and  
4 monitoring the operation of the accelerometer;  
5 wherein monitoring the operation of the accelerometer comprises  
6 monitoring the accelerometer for instability to indicate a  
7 malfunction of the accelerometer or an excessive external  
8 acceleration.
- 1 30. A method of determining the state-of-health for a sensor assembly adapted  
2 to sense seismic energy, including an accelerometer, comprising:  
3 exciting the accelerometer with a bitstream; and  
4 acquiring, analyzing and judging an output signal generated by the

- 5                    accelerometer;
- 6                    wherein judging an output signal comprises judging a magnitude of
- 7                    the output signal to indicate a malfunction of the accelerometer.
- 1   31.   A method of determining the state-of-health for a sensor assembly adapted
- 2                    to sense seismic energy, including an accelerometer, comprising:
- 3                    exciting the accelerometer with a bitstream; and
- 4                    acquiring, analyzing and judging an output signal generated by the
- 5                    accelerometer;
- 6                    wherein judging an output signal comprises judging a phase response of
- 7                    the output signal to indicate a malfunction of the accelerometer.
- 1   32.   A method of determining the state-of-health for a sensor assembly adapted
- 2                    to sense seismic energy, including an accelerometer, comprising;
- 3                    exciting the accelerometer with a bitstream; and
- 4                    acquiring, analyzing and judging an output signal generated by the
- 5                    accelerometer;
- 6                    wherein judging an output signal comprises judging a total harmonic
- 7                    distortion of the output signal to indicate a malfunction of the
- 8                    accelerometer.
- 1   33.   A method of determining the state-of-health for a sensor assembly adapted
- 2                    to sense seismic energy, including an accelerometer, comprising:
- 3                    operating the accelerometer for a period of time; and
- 4                    analyzing an output signal generated by the accelerometer;
- 5                    wherein analyzing an output signal comprises detecting an excessive
- 6                    root-mean-square amplitude response of the output signal to
- 7                    indicate a malfunction of the accelerometer or a noisy environment.
- 1   34.   A method of determining the state-of-health for a sensor assembly adapted
- 2                    to sense seismic energy, including an accelerometer, comprising:
- 3                    operating the accelerometer; and
- 4                    analyzing an output signal generated by the accelerometer;
- 5                    wherein analyzing an output signal comprises analyzing an offset and a
- 6                    gravity cancellation magnitude of the output signal to detect a
- 7                    change in the inclination of the accelerometer.

- 8 35. A method of determining the state-of-health for a sensor assembly adapted  
9 to sense seismic energy including three accelerometers, comprising:  
10 operating the accelerometers; and  
11 monitoring one or more output signals generated by the accelerometers;  
12 wherein monitoring one or more output signals generated by the  
13 accelerometers comprises monitoring a vector sum of the self-  
14 measured coefficients of gravity of the output signals to detect a  
15 malfunction of the sensor assembly.
- 1 36. A method of determining the state-of-health for a sensor assembly adapted  
2 to sense seismic energy, including three accelerometers, comprising:  
3 operating the accelerometers;  
4 driving two of the accelerometers at a reference frequency;  
5 monitoring an output signal generated by the undriven accelerometer; and  
6 rotating through all the accelerometers;  
7 wherein monitoring an output signal comprises monitoring the  
8 magnitude of the reference frequency in the output signal  
9 of the undriven accelerometer to detect a malfunction of the sensor  
10 assembly.
- 1 37. A method of determining the state-of-health for a sensor assembly adapted  
2 to sense seismic energy, including one or more accelerometers, comprising:  
3 operating the accelerometers for a period of time;  
4 removing DC offset from one or more output signals generated by the  
5 accelerometer to produce one or more resulting signals;  
6 transforming the resulting signals from the accelerometers from  
7 Cartesian coordinates into polar coordinates; and  
8 analyzing the polar coordinates;  
9 wherein analyzing the polar coordinates comprises analyzing one or  
10 more peak and root-mean-square amplitude results to indicate a  
11 malfunction of the sensor assembly or a noisy acquisition  
12 environment.
- 13 38. A method of determining the state-of-health for a sensor assembly adapted  
14 to sense seismic energy including one or more accelerometers, comprising:

- 15 (a) operating the accelerometers;  
16 (b) monitoring one or more output signals generated by the  
17 accelerometers;  
18 (c) analyzing the output signals;  
19 (d) changing the orientation of the sensor assembly; and  
20 (e) repeating steps (b), (c) and (d) for a plurality of orientations;  
21 wherein analyzing the output signals comprise calculating the sensor's  
22 angles with respect to gravity from a vector sum of the self-  
23 measured coefficients of gravity in any orientation; and  
24 wherein analyzing the output signals further comprises analyzing  
25 sensor's angles with respect to gravity to indicate a malfunction of  
26 the sensor assembly.